

RHIC Retreat 2000

Bunch Intensity from the Injectors: Beyond 10^9

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Assumptions:

- 1. Tweaking and stroking the injectors will not likely yield a factor of two.**
- 2. We haven't drained the well of bunch merging tricks.**
- 3. RF gymnastics can be reliable, on-demand, operational gear.**

The Principle

We endeavor to funnel as much Tandem beam in each RHIC bunch as possible. The main limitation is keeping the accumulated emittance within the RHIC requirements.

Now we have one Tandem pulse going into one RHIC bunch. We have just enough longitudinal emittance to spare to get two Tandem pulses into a RHIC bunch.

The key **challenge** is to get all the Booster beam into one bunch before going through the BTA foil.

Longitudinal Emittance

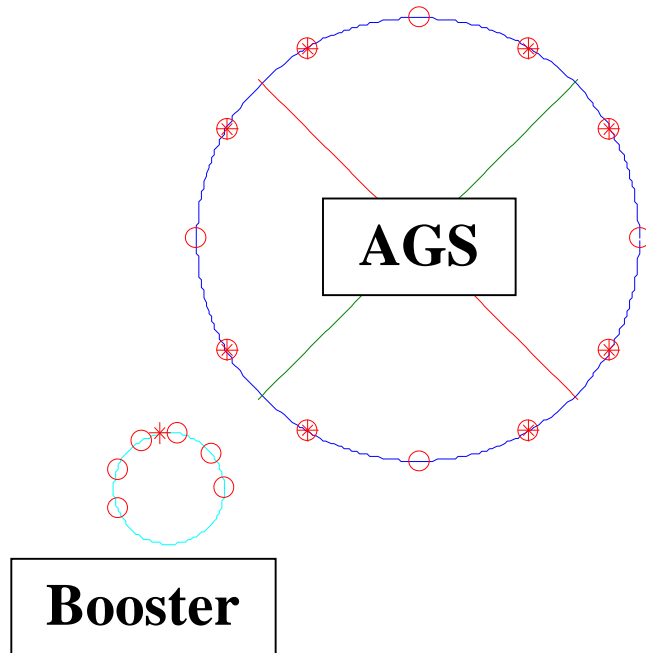
Bad News:

- Now we are full up at 0.3 eVs/n
- We have to earn a factor of two improvement in order to do another merge

Good News:

- The bulk of the emittance comes from the BTA foil...energy loss, energy straggling.
- One-bunch on the foil can greatly reduce the emittance *growth*.

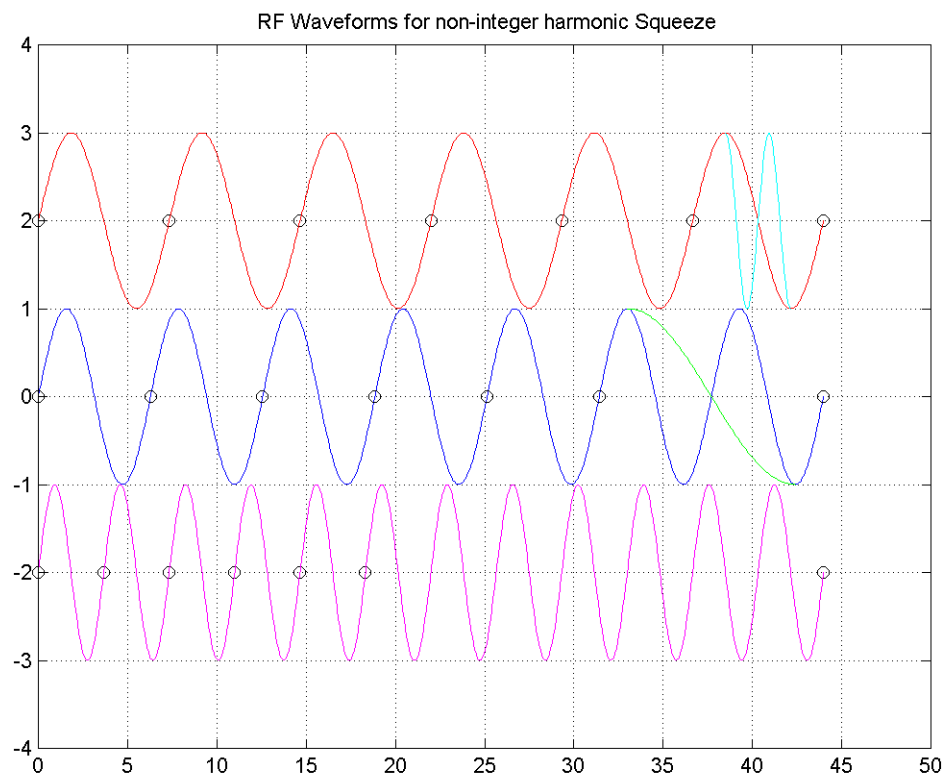
The Scheme



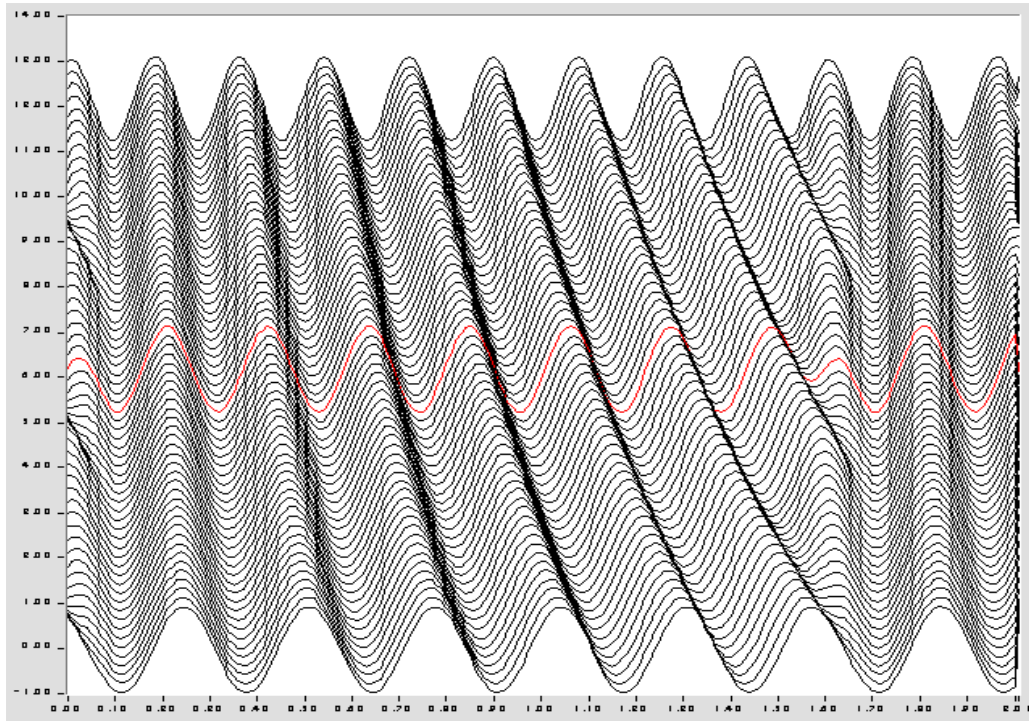
Eight cycles of the Booster
with one bunch fill **Four pairs**
of bunches in the AGS on
harmonic 12

Then merge the pairs into four
bunches for RHIC

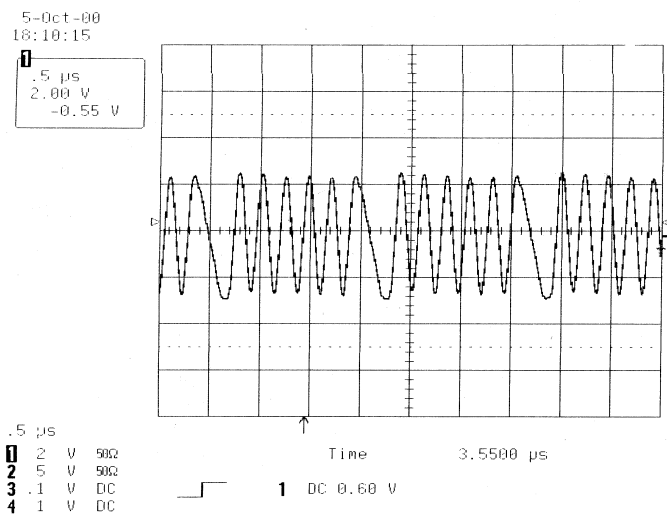
RF Waveforms for the Bunch Squeeze, $h:6 \rightarrow 12$



Waveform for Continuously Changing rf Harmonic Number



Measured rf drive signal



Measured high voltage on cavity

Benefits of One Bunch in the Booster

- **Emittance growth from the foil can be reduced**
 1. bunches can be put into the middle of AGS buckets even with beam speed loss in the foil
 2. Aspect ratio in phase space changes such that matching in AGS is possible, 100 kV
- **A5 Injection kicker**
 1. pulse length can be much shorter
 2. extra fall time due to empty bucket in AGS
 3. lower charge state possible (+31) in Booster because frequency need not be so high
- **Merge in AGS, as opposed to debunch/rebunch, will eliminate “baby” bunches**

Conclusions

- A factor of two in bunch intensity can likely be achieved for the RHIC bunches
- The longitudinal emittance specification can still be achieved by reduction of emittance growth
- The key to this mode of operation is compressing all the Booster beam into one bunch
- The Booster high level rf system for BandII can provide the specialized rf waveform need to change the harmonic number continuously from 6 to 9
- The six bunches on harmonic number 9 can be coalesced into one with a linearized waveform made by the BandIII cavities

LHC

7 Injectors

One of the big assets of the LHC project is the existence on the CERN site of a reliable chain of high-performance accelerators which are well suited to providing the LHC with its supply of protons. All CERN's proton machines play their role in the injection scheme for the LHC: the 50 MeV proton linac (Linac 2), the 1 GeV PS Booster (PSB), the 26 GeV PS, and finally the SPS which will inject protons at 450 GeV — its top energy — into the LHC. Two new beam lines at this energy are required to allow protons to be fed to the LHC in both the clockwise and anticlockwise direction, see Section 6, Fig. 1.

7.1 Injection scheme

The injector chain has to deliver a beam quality at least compatible with the nominal LHC performance. The beam has to fit into the tiny LHC dynamic aperture at injection while providing enough intensity to ensure high luminosity at collision. The longitudinal emittance of the bunches is determined by the need to keep the growth rate due to intrabeam scattering in the LHC within tolerable limits.

Experience shows that an injector machine should be capable of 'saturating' the client accelerator. That is why a higher performance level is aimed at, which ultimately should enable filling the LHC up to the beam-beam limit and bring the additional advantage of a welcome operational margin for the nominal beam. The beam parameters required at LHC injection are shown in Table 1:

Table 1: LHC injection beam parameters

Number of protons per bunch – nominal		10^{11}
– beam-beam limit		$1.7 \cdot 10^{11}$
Bunch spacing	[ns]	24.95
Transverse emittance (r.m.s., normalized)	[μm]	3.5
Longitudinal emittance	[eV.s]	1

This beam cannot be produced by the injector chain as it stands now; most of the modifications, discussed below, are dictated by beam dynamics constraints in the acceler-